Coastal Benthic Optical Properties (CoBOP) of Coral Reef Environments: Small Scale Fluorescent Optical Signatures and Hyperspectral Remote Sensing of Coral Reef Habitats

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LONG-TERM GOAL

My principal goal is to understand the mechanistic basis for changes in the flourescent signatures, both host and algal symbiont, of corals. Changes in the spectral quantity and quality of visible and ultraviolet radiation will have effects on the quantum yield of photosynthesis and affect the fluorescent signatures of the algal symbionts as will changes in the temperature of the surrounding seawater. Additionally, I wish to relate bottom reflectance measurements of coral reefs to hyperspectral remote sensing reflectance measurements made from buoys or airborne platforms.

OBJECTIVES

The Coastal Benthic Optical Properties (CoBOP) project is directed at understanding the optical properties of coastal benthic communities in general, and in particular, coral reefs. Coral reef communities are coastal areas of high water transparency which make them ideal systems to study optical signatures originating from the benthos. The scientific objectives of my project are:
1. to attain optical closure for coral reef communities
2. to understand the causes of benthic optical variability
a. determine the spectral signatures, both fluorescent and reflectance, of reef organisms
b. determine the effects of the physical environment on the physiology of reef organisms and assess those effects on optical signatures
c. identify the temporal and spatial scales of variability in these optical signatures
d. to help evaluate the use of underwater systems to quantitatively measure fluorescent optical signatures.

APPROACH

The approach is an interdisciplinary one that looks at two specific questions.
1) measure photosynthesis and active fluorescence of two species of reef forming corals (*Montastraea faveolata* and *Montastraea cavernosa* at 10 and 18 m) to examine the relationship between chlorophyll fluorescence and photosynthesis in collaboration with Drs. Paul Falkowski and Maxim Gorbunov.
2) measure the bottom reflectance of coral reefs and relate those optical signals to hyperspectral measurements of remote sensing reflectance using measurements of apparent and inherent optical properties and modeling in collaboration with Drs. Charles Mazel and Robert Maffione.

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WORK COMPLETED

During this proposal the CoBOP program was able to establish its long-term research site on Lee Stocking Island in the Bahamas. A fast repetition rate fluorometer has been tested in several field seasons and proven to provide accurate, and non-invasive, measurements of the quantum yield of phototosystem II. This instrument continues to be used in studies of photosynthesis and environmental stress on corals. During the 1999 and 2000 field seasons measurements of bottom reflectance and hyperspectral remote sensing reflectance using the Satlantic TSRB buoy and an airborne hyperspectral sensor were conducted. I continue to work on the analysis of the hyperspectral data using "fuzzy analysis" with the help of Dr. Janet Campbell here at UNH and have will be collaborating with Dr. Curt Mobley on the use of his LUT (look up table) protocols with Hydrolite. Lastly, I have isolated, sequenced, and cloned genes for the green fluorescent protein in two important members of the scleractinian coral fauna, *Montastraea cavernosa* and *M. faveolata*.

RESULTS

Results from the fast repetition rate fluorometer (FRRF) clearly show a diel cycling of the quantum yield of PSII fluorescence related to non-photochemical quenching during exposure to high irradiances of visible and UV radiation (Fig. 1). FRRF measurements can also be used to detect temperature induced "bleaching" or the loss of its algal symbionts. A manuscript has been published in Marine Ecology Progress Series. Fluorescent proteins are a significant contributor to coral color. Our work to date has included isolation and sequencing of green fluorescent protein genes and studies on the localization of GFP in the coral tissue in order to understand its function (Fig.2) During both the 1999 and year 2000 field seasons a complete set of measurements related to supporting the hyperspectral remote sensing and to test for optical closure on shallow coral reef sites was collected. A analysis and comparison of various techniques to obtain remote sensing reflectance (L_w/E_d) has ***sh***own fairly good agreement with atmospherically corrected hyperspectral data taken over

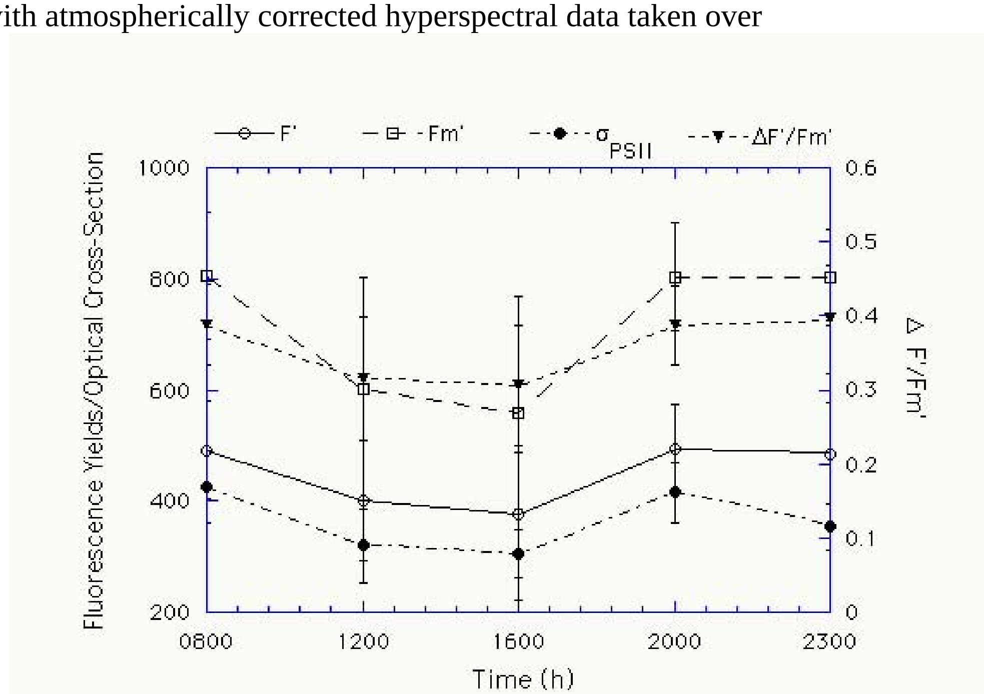

Figure 1. Diel cycle of <u>in</u> <u>situ</u> chlorophyll fluorescence yields at steady-state (=light acclimatized) and dark acclimated, including the quantum yield of chlorophyll fluorescence (F'/F$_m$') in PSII, and the functional absorption cross section ($_{PSII}$) for PSII. Mean (± SD) of six samples for Montastraea faveolata,

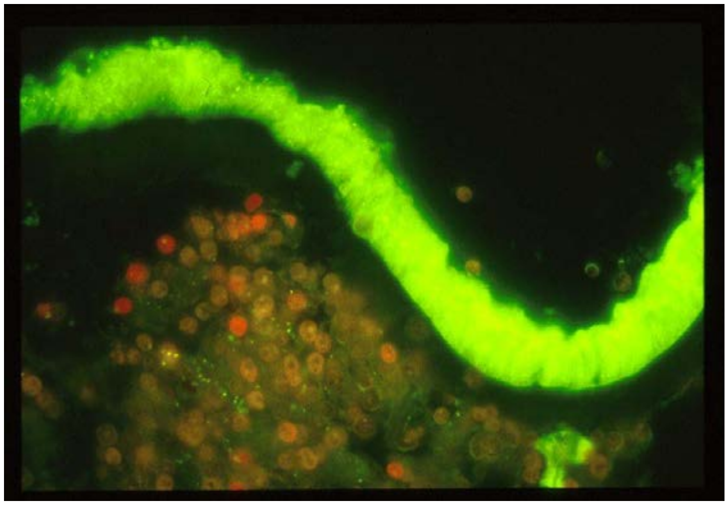

Figure 2. Green fluorescent protein in the epithelial cells of the coral <u>Montastraea</u> <u>cavernosa,</u> The sample is fixed decalcified tissue examined under an epifluorescent microscope. Note the red chlorophyll fluorescence from the symbiotic zooxanthellae

Horseshoe Reef in 1999. Presently the analysis of these data sets is focused on extracting meaningful information from the remote sensing reflectance on the dominant functional groups contributing to the spectral shape of the remote sensing reflectance and applying that information to the airborne imagery. Early work with "fuzzy analysis" techniques has shown that we can separate living corals from sand and we continue to apply this technique to other functional members of the coral reef community (Fig. 3).

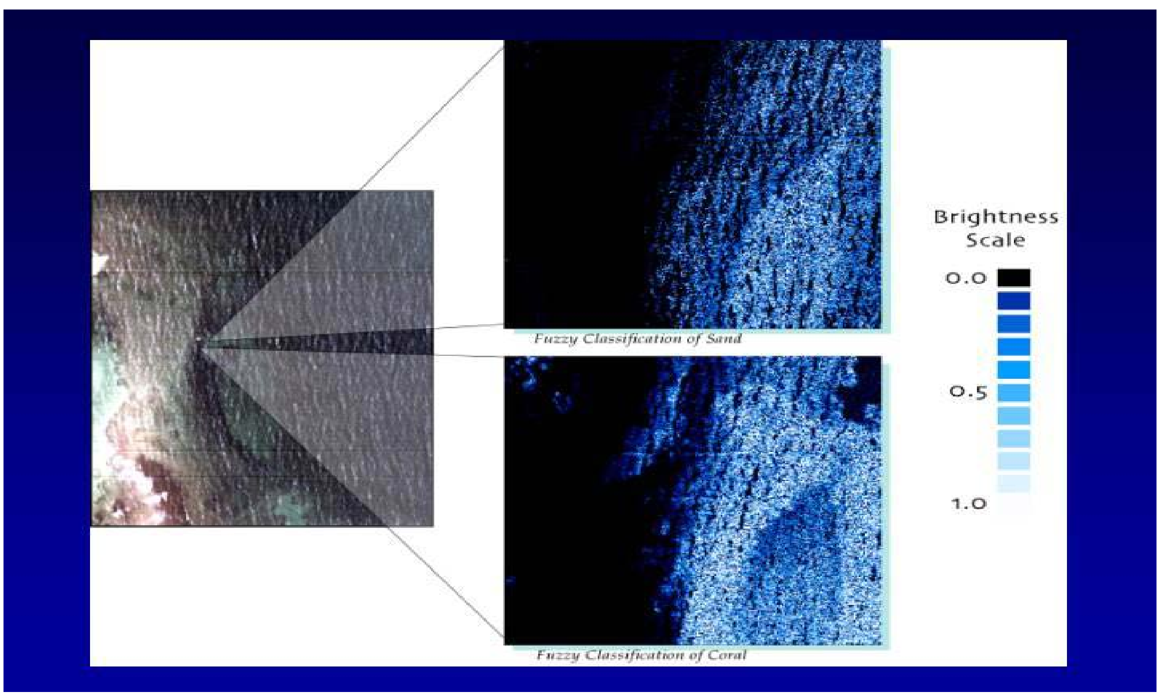

Figure 3. Initial fuzzy analysis for Horseshoe Reef, LSI 1999. The analysis correctly identified those pixels consisting entirely or partially of sand or coral.

IMPACT/APPLICATIONS

Two specific impacts of the work completed to date are the use of an underwater FRRF for obtaining fluorescent signatures *in situ* and using this instrumentation as a tool to detect whether corals have been exposed to environmental stress that might lead to bleaching or mortality. Secondly, the successful use of several different methods, including the Satlantic hyperspectral TSRB buoy, to obtain coordinated measurements of hyperspectral remote sensing and inherent optical properties on several reefs around Lee Stocking Island is providing a large database to test for optical closure and to ascertain the utility of hyperspectral remote sensing techniques as a mapping tool for shallow water benthic habitats.

TRANSITIONS

The data collected from the 1998 -2000 field seasons is being analyzed and prepared for publication in Limnology and Oceanography. CoBOP investigators, and others, recently published their work in a Special Volume in Limnology and Oceanography on Shallow Water Optics for which I was the Special Volume Editor. I have recently learned from the L&O editor that papers from this volume are the most downloaded pdfs published so far this year.

RELATED PROJECTS

Charlie Mazel-ONR, CoBOP
Robert Maffione-ONR, CoBOP
Paul Falkowski-ONR, CoBOP
Dave Phinney-ONR, CoBOP
Charlie Yentsch-ONR, CoBOP

PUBLICATIONS

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